Wilson Bull., 106(3), 1994, pp. 514–521

WINTER SURVIVAL RATES OF A SOUTHERN POPULATION OF BLACK-CAPPED CHICKADEES

ERICA S. EGAN[1] AND MARGARET C. BRITTINGHAM[1]

ABSTRACT.—Using the Jolly-Seber method of capture and reobservation, we estimated monthly winter (1989–1990, 1990–1991) survival rates of 321 color-marked Black-capped Chickadees (*Parus atricapillus*) and compared survival rates among three habitat types in central Pennsylvania: suburban habitat, forest habitat with supplemental food, and forest habitat without supplemental food. Chickadee survival rates differed ($P = 0.018$) among habitats. Monthly winter survival rates ($\bar{x} \pm$ SE) for chickadees in the forest habitat without supplemental food (0.81 ± 0.05) differed from both the forest habitat with supplemental food (0.93 ± 0.02) and the suburban habitat with supplemental food (0.94 ± 0.02). Survival rates of chickadees did not differ ($P > 0.25$) between the two habitat types where supplemental food was available. The difference in survival rates between chickadees with and without access to supplemental food was greatest in October and March, months when dispersal of chickadees may occur, suggesting that feeders were influencing movements of chickadees (survival on the study site) rather than actual survival. *Received 24 June 1993, accepted 1 Feb. 1994.*

The range of the Black-capped Chickadee (*Parus atricapillus*) extends from Alaska, across Canada, and into the northern United States (Smith 1991). Pennsylvania is on the southern edge of the Black-capped Chickadee's range. In rural northern areas with seasonally severe temperatures, survival rates of Black-capped Chickadees with access to supplemental food are higher than survival rates of chickadees without access to bird feeders (Brittingham and Temple 1988, Desrochers et al. 1988). However, the effect of supplemental feeding on survival rates of chickadees at the southern edge of their range, where winter temperatures are much milder, is unknown.

In addition to occupying a wide geographic range, Black-capped Chickadees are found in a wide range of habitats and are common in both forest and suburban areas during the winter. Suburban habitats differ from forest habitats in a number of ways, some of which may be beneficial to wintering chickadees. For example, bird feeders are abundant in most suburban areas. Other factors of suburbanization that may benefit chickadees include access to water during winter, decreased abundance of native predators, increased day length from artificial lights, and increased temperatures (Erz 1966). On the other hand, some changes associated with suburbanization, such as an increase in cats, dogs, and rats near human dwellings (Wilcove 1985), could result in a decrease in survival rates of birds. In addition, birds in suburbia are exposed to a variety of

[1] School of Forest Resources, The Pennsylvania State Univ., University Park, Pennsylvania 16802.

anthropogenic hazards, including cars and windows (Banks 1979, Hickey and Brittingham 1991, Klem 1991).

We compared winter survival rates of Black-capped Chickadees among three habitat types (suburban, forest without feeders, and forest with feeders) to determine whether survival rates differed among the surburban and the two forest habitats and to isolate the influence of supplemental feeding on survival rates from other aspects of suburbanization that may influence winter survival rates. We tested whether chickadees with access to feeders (suburban and forest with feeders) had higher survival rates than chickadees without access to supplemental food (forest without feeders) and whether the magnitude of the effect of supplemental food varied with temperature.

STUDY SITES AND METHODS

Study sites.—We established study sites within three habitat types (suburban, forest without feeders, and forest with feeders) and attempted to maintain approximately the same number of marked Black-capped Chickadees in each habitat type. We banded chickadees at one forest site with feeders, at three suburban sites, and at three forest sites where feeders were not available. Multiple banding sites were necessary for the latter two habitat types because chickadees in those areas were more difficult to capture.

The suburban sites were located in College Heights, Park Forest, and Woody Crest neighborhoods, State College, Centre County, Pennsylvania. These sites were approximately 1.2 km from each other. All suburban sites had mature trees and bird feeders located throughout. Average age of the homes in each neighborhood ranged from 26 to 70 years.

The three forest sites without feeders were located in Rothrock State Forest, Huntingdon County, Pennsylvania. The area was a mature forest dominated by oak (*Quercus* spp.), maple (*Acer* spp.), and pine (*Pinus* spp.), with small sapling and pole stands, gullies, steep talus slopes, and intermittent streams intermixed throughout the area. Two of the forest sites were approximately 2 km apart, and the third site was approximately 4 km from the other two sites. All sites were at least 1.6 km from residential areas, which might have been a source of supplemental food or domestic predators. The forest site with feeders was located at Shaver's Creek Nature Center within Rothrock State Forest, Huntingdon County, Pennsylvania. The feeders were filled year-round with black-oil sunflower seeds. Suet feeders also were present during the winter months. The nature center was approximately 4 km from the other forest sites.

Suburban survey.—Thirty residents were randomly selected from each neighborhood and asked to participate in the survey. Twenty-four residents from the three neighborhoods were willing to participate. Residents were asked five questions—(1) What is the size of your lot? (2) Do you have a bird feeder? If yes, during what seasons do you keep the feeder filled? What type of bird seed is placed in the feeder? (3) Do you have a bird bath? (4) Do you have a bird house? (5) Do you own a pet? If yes, what type of pet? and to your knowledge has the pet ever captured any birds?

Capture and marking.—At each site, we captured Black-capped Chickadees using mist nets. On the suburban sites, we also used feeder traps with a manual release. We began to capture Black-capped Chickadees in September in both 1989 and 1990 and continued capturing birds until the following March of each year. The majority of the banding occurred in October and November except at the Shaver's Creek Nature Center site during the second

year when we banded primarily in early January. We banded each Black-capped Chickadee with a USFWS aluminum leg band and three colored leg bands. Each individual had a unique combination of colored bands so birds could be visually identified in the field. From September through December, birds were aged from shape and wear of the rectrices and recorded as juveniles or adults (Meigs et al. 1983). When we were unsure, individuals were recorded as unknown. After December, the ages of newly captured birds were also recorded as unknown. All banded birds that were still alive the following fall were classified as adults. We did not determine the sex of banded chickadees.

Monthly survival rates.—From October–May, we attempted to relocate visually each Black-capped Chickadee every month. Observations were made throughout the day, and we regularly searched areas adjacent to our sites for birds which may have moved short distances. Monthly survival rates ($\bar{x} \pm$ SE) of chickadees at each study site were calculated by the Jolly-Seber method that uses capture and reobservation data (Jolly 1965, Seber 1965, Clobert et al. 1987). We did not calculate monthly estimates for months when fewer than five individuals were captured or reobserved. These data gaps occurred primarily early in the winter when we had few marked individuals. We used one-way and two-way analysis of variance and a Tukey's test ($\alpha = 0.05$) to test for differences in average monthly survival rates among different groups of chickadees (Brittingham and Temple 1988).

Survival rates and temperature.—We obtained data on ambient temperatures from the National Oceanic and Atmospheric Administration (NOAA) weather station in State College, Pennsylvania. We did not obtain separate temperature data for the forest sites, but presumably these sites would be a few degrees colder on average than the suburban sites (Erz 1966).

In northern areas, winter survival rates of chickadees are dependent to some extent on the interaction between winter severity and winter food supply (Brittingham and Temple 1988, Smith 1991). To determine if winter survival rates differed with ambient temperatures and food supply at the southern edge of the chickadee's range, we examined the effects of temperature on survival rates of chickadees with and without supplemental food in a number of ways. First, using analysis-of-covariance, we tested whether mean monthly survival rates of chickadees with and without supplemental food varied linearly with mean monthly temperature.

Fat deposition in chickadees and other small birds is maintained at a level that allows an individual to survive overnight under expected or average weather conditions (Evans 1969). As a result, monthly survival rates may be less dependent on the actual value of the mean temperature and more dependent on how close the mean temperatures are to the normal or "expected" temperatures. For each month, we used the 30-year (1951–1980) mean temperature as the expected temperature. We separated the months of our study into two groups, months when the mean temperature was at or above average and months when the temperature was below average, and tested whether survival rates of chickadees with and without supplemental food differed between months when the monthly temperature was above or below normal.

Brittingham and Temple (1988) reported that the positive effect of supplemental feeding on survival rates was most pronounced during extended periods of cold temperatures (>5 days below −18°C). They suggested that supplemental food was relatively unimportant during mild or average winter weather but was extremely important during extended cold spells. In Pennsylvania, the periods of cold temperatures were not as cold or as long as in Wisconsin. During the two winters of this study, the coldest mean temperature that occurred for more than four consecutive days within a month was −6.67°C. Therefore, to test whether the effect of supplemental feeding was greatest during months with extended periods of cold temperatures, we categorized the months as months when the temperature fell below

TABLE 1

CAPTURE AND OBSERVATION DATA USED TO CALCULATE SURVIVAL RATES OF CHICKADEES IN SUBURBAN AND FOREST HABITATS (1989–1991)

Study site[a]	Habitat[b] type	Number of chickadees banded	Age of[c] chickadees			Number of recaptures and observations
			Adult	Juv	Unkn	
RR1	FNF	45	29	22	1	169
RR2	FNF	31	24	9	8	132
WDF	FNF	41	17	8	28	92
SSC	FF	123	33	9	99	349
PFS	SF	34	24	14	2	141
CHS	SF	29	16	12	4	146
WCS	SF	18	4	4	10	58

[a] Study site: RR1 = Rothrock forest site 1; RR2 = Rothrock forest site 2; WDF = Whipple Dam forest site; SSC = Shaver's Creek forest with supplemental food; PFS = Park Forest suburban site; CHS = College Heights suburban site; WCS = Woody Crest suburban site.

[b] Habitat type: FNF = forest habitat, no feeders; FF = forest habitat with feeders; SF = suburban habitat with feeders.

[c] Number of chickadees does not equal number of banded chickadees because chickadees banded in year 1 and still present on the site in year 2 are counted twice.

−6.67°C on four or more consecutive days and months when the temperature did not fall below −6.67°C on at least four or more consecutive days and tested whether survival rates of chickadees with and without supplemental food differed between the two groups of months.

RESULTS

Study site survey.—Average size (±SE) of the suburban area home lots was 0.24 ha ± 0.02 with dense vegetation or patches of native woodlands often adjacent to at least one side of the lot. Fifty-eight percent of those surveyed had bird feeders, 29% had bird baths, and 63% had bird houses in their yards. Seventy-five percent of those who fed birds maintained feeders year-round with a variety of foods. Thirty percent of the residents owned cats and 48% owned dogs. Respondents reported that 100% of the cats and 9% of the dogs had caught birds.

Banding data.—We banded 321 chickadees and made 1087 reobservations of these birds (Table 1). When chickadees of unknown age were excluded, we detected no difference ($\chi^2 = 4.4$, df = 2, $P > 0.1$) in the age composition of birds banded on the three types of sites. The percentage of adults was 64% on the forested sites where supplemental food was not available, 79% on the forested site where supplemental food was available, and 59% on the suburban sites. In addition, the percentage of adults in the population did not differ ($\chi^2 = 0.12$, df = 1, $P > 0.5$) between sites where supplemental food was not available and sites where supplemental food was available (64% vs 66%) (Table 1).

Survival rates and habitat type.—Average monthly survival rates (N = 28) of Black-capped Chickadees differed among habitat types (F = 4.73, df = 2, 25, P = 0.018). Average monthly survival rates (± SE) of chickadees on the forest sites where supplemental food was not available (0.81 ± 0.05, N = 10) differed significantly ($P < 0.05$) from survival rates of chickadees on both the forest site with supplemental food (0.93 ± 0.02, N = 7) and the suburban sites (0.94 ± 0.02, N = 11) where supplemental food was also available. We did not detect differences in survival rates of chickadees ($P > 0.25$) between the forest habitat with supplemental food and the suburban habitat. Because monthly survival rates did not differ between the two habitat types where supplemental food was available (suburban and forest with feeder) and both differed from the habitat type where supplemental food was not available (forest without feeders), all remaining analyses were between sites where feeders were available (suburban and forest with feeder combined) and sites where supplemental food was not available.

Monthly variation and survival rates.—Survival rates varied among months (F = 2.90, df = 5, 16, P = 0.05), with the presence of supplemental food (F = 22.58, df = 1, 16, $P < 0.0001$), and with the interaction among months and presence of supplemental food (F = 3.14, df = 5, 16, P = 0.04) (Fig. 1). In all months, survival rates of chickadees with access to supplemental food was higher than survival rates of chickadees without access to supplemental food, but the difference was most pronounced in October and March. During those months, survival rates of individuals without access to supplemental food fell to approximately 0.60, but survival rates of birds with access to supplemental food remained >0.90.

Survival rates and temperature.—During the months of our study, the mean ($\bar{x}$ ± SE) monthly temperature was 4.1°C ± 5.6 and the mean monthly minimum temperature was −0.94°C ± 4.9. During one month, the temperature fell below −13°C on 14 days and below −21°C on one day. During a second month, the temperature fell below −10°C on 4 days and below −15°C on one day. The mean monthly temperature was at or above average during nine months and was below average during two months. Mean temperatures for each month did not exceed or fall below normal (1951–1980) by more than 2.8°C except December 1989 which was 6.8°C below normal. During the two winters of this study, temperatures fell below −6.67°C on four or more consecutive days during four months.

We did not detect a difference in survival rates with mean monthly temperature (F = 1.75, df = 1, 25, P = 0.20) or between months when the mean temperature was below normal and months when it was above normal (F = 3.25, df = 1, 25, P = 0.08). In addition, we did not detect

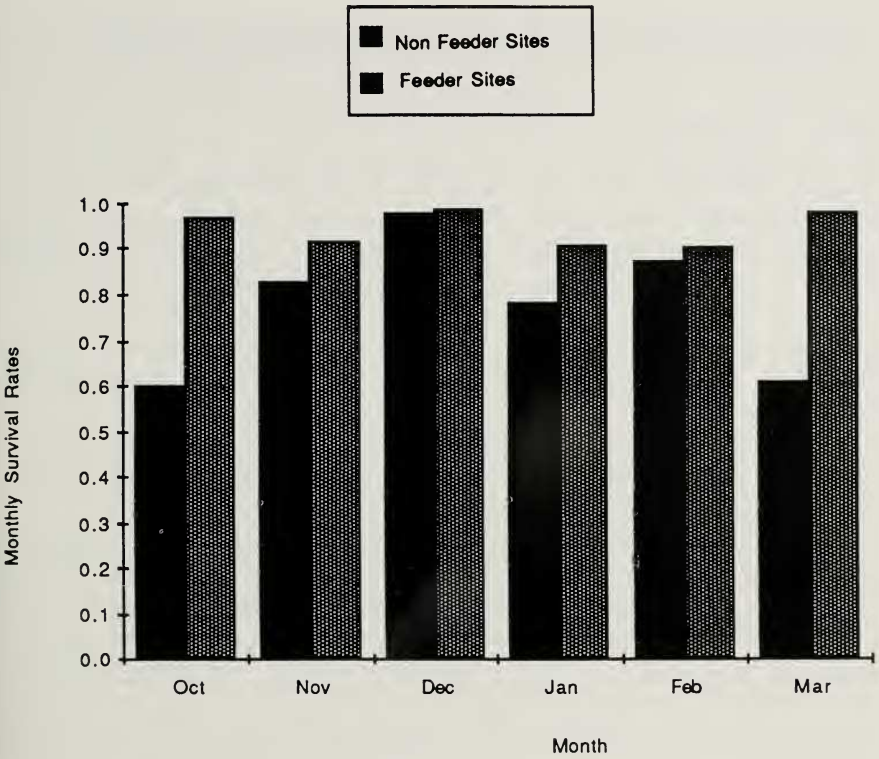

FIG. 1. Mean monthly survival rates of chickadees with and without access to bird feeders in Centre and Huntingdon counties, Pennsylvania, during the winter (1989–1991).

a difference in survival rates between cold months (≥4 consecutive days below −6.67°C) and moderate weather months (≤4 consecutive days above −6.67°C) ($F = 1.20$, df = 1, 25, $P = 0.28$).

DISCUSSION

Numerous studies have shown that Black-capped Chickadees and European tits (*Parus* spp.) with a source of supplemental food have higher survival rates than individuals without access to supplemental food (Jansson et al. 1981, Brittingham and Temple 1988, Desrochers et al. 1988, Orell 1989). Bird feeders were common throughout the suburban sites, and all the chickadees banded on those sites used the feeders. Therefore, we attributed the positive effect of suburbanization on survival rates to the numerous bird feeders present in the suburban habitat.

Wilcove (1985) speculated that effects of suburbanization, such as in-

creased abundance of domestic predators and higher disturbance levels, may negatively affect survival rates, but we did not detect any differences in the survival rates of chickadees in the suburban habitat and the forest habitat with supplemental food. Perhaps an increase in numbers of domestic predators in suburban areas was offset by a decrease in native predators. On the other hand, chickadees with access to feeders may not have to expend as much time searching for food, thus, decreasing their time exposed to predators (Powell 1974, Jansson et al. 1981), or they may be less vulnerable to domestic predators than other bird species.

The survival rates we estimated for our chickadee populations describe continued presence on the study site. The complement of these rates include both mortality and emigration. We had no way of distinguishing between the two types of losses because birds were never found dead. However, the timing of disappearance and the environmental circumstances occurring at the time of disappearance provide evidence to separate the two types of losses.

The greatest difference between survival rates of chickadees with and without supplemental food occurred in October and March. Concentrated movements of chickadees occur in the fall and spring (Smith 1991). Chickadee movements in the fall (e.g., juvenile dispersal) have usually stabilized by late October (Weise and Meyer 1979, Desrochers and Hannon 1989). In the spring, chickadee movements may begin as early as mid-March when individuals of low dominance status begin to wander (Smith 1991). The timing of loss in our study suggests that individuals which disappeared may have emigrated instead of died. The environmental conditions in October and March support this hypothesis. October is generally a mild month and natural food supplies are still abundant. March can be a time of food shortage, but at least during this study, March temperatures were above or near normal. Consequently, we suspect supplemental feeding in Pennsylvania had an effect on movement instead of on actual survival. Supplemental feeding may have caused chickadees to settle earlier in the fall and move out later in the spring.

Our results differ from those reported in Wisconsin where survival rates of chickadees were affected by temperature and the benefits of feeders were most pronounced during extended periods of cold temperatures (Brittingham and Temple 1988). In addition, the authors provided strong evidence that bird feeders influenced actual survival rates instead of movement (Brittingham and Temple 1988). We did not find any relationship between cold temperatures and winter survival rates of Black-capped Chickadees in Pennsylvania. The two winters during this study were normal winters for central Pennsylvania, thus the chickadees may have had sufficient reserves for those temperatures. During an unusually cold win-

ter, we might see a relationship between survival rates, supplemental food, and temperatures.

ACKNOWLEDGMENTS

We thank G. R. Potter for permission to use Shaver's Creek Environmental Center as a study site and Doug Wentzel and the staff at Shaver's Creek for banding assistance. W. M. Tzilkowski, R. H. Yahner, S. M. Smith, C. R. Blem, and an anonymous reviewer provided helpful comments on an earlier draft of this manuscript. Our research was supported by the Pennsylvania Agricultural Experiment Station.

LITERATURE CITED

Banks, R. C. 1979. Human related mortality of birds in the United States. U.S. Fish and Wildl. Serv. Spec. Sci Rep. 215.

Brittingham, M. C. and S. A. Temple. 1988. Impacts of supplemental feeding on survival rates of Black-capped Chickadees. Ecology 69:581–589.

Clobert, J., J. D. Lebereton, and D. Allaine. 1987. A general approach to survival rate estimation by recaptures or resightings of marked birds. Ardea 75:133–142.

Desrochers, A. and S. J. Hannon. 1989. Site-related dominance and spacing among winter flocks of Black-capped Chickadees. Condor 91:317–323.

———, ———, and K. E. Nordin. 1988. Winter survival and territory acquisition in a northern population of Black-capped Chickadees. Auk 105:727–736.

Erz, W. 1966. Ecological principals in the urbanization of birds. Ostrich Suppl. 6:357–363.

Evans, P. R. 1969. Winter fat deposition and overnight survival of yellow buntings (*Emberiza citrinella* L.). J. Anim. Ecol. 38:415–423.

Hickey, M. B. and M. C. Brittingham. 1991. Population dynamics of Blue Jays at a bird feeder. Wilson Bull. 103:403–416.

Jansson, C., J. Ekman, and A. Von Bromssen. 1981. Winter mortality and food supply in tits *Parus* spp. Oikos 37:313–322.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration—stochastic model. Biometrika 52:225–247.

Klem, D. 1991. Glass and bird kills: an overview and suggested planning and design methods of preventing a fatal hazard. Pp. 99–103 *in* Wildlife conservation in metropolitan environments (L. W. Adams and D. L. Leedy, eds.). Proc. Nat. Symp. on Urban Wildl. Nat. Inst. for Urban Wildl.

Meigs, J. B., D. C. Smith, and J. Van Buskirk. 1983. Age determination of Black-capped Chickadees. J. Field Ornithol. 54:283–286.

Orell, M. 1989. Population fluctuations and survival of Great Tits *Parus major* dependent on food supplied by man in winter. Ibis 131:112–127.

Powell, G. V. N. 1974. Experimental analysis of the social value of flocking by Starlings (*Sturnus vulgaris*) in relation to predation and foraging. Anim. Behav. 22:501–505.

Seber, G. A. 1965. A note on the multiple-recapture census. Biometrika 52:249–259.

Smith, S. M. 1991. The Black-capped Chickadee behavioral ecology and natural history. Cornell Univ. Press, Ithaca, New York.

Weise, C. M. and J. R. Meyer. 1979. Juvenile dispersal and development of site-fidelity in the Black-capped Chickadee. Auk 96:40–55.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211–1214.